Emission arrays based on carbon nanostructures for vacuum electronics

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The use of existing methods of formation leads to the degradation of the emission properties of the active region of the structures of vacuum electronics. Based on this, there is the problem of finding technologies for the formation of field emitters based on carbon nanostructures using plasma. In this study, we studied the formation modes of a field emitter with an active region based on carbon structures using plasma etching and deposition technologies to form a model of a field emitter cell.

The experimental model is a small insulating silicon substrate. For the formation of a diffusion barrier, a dielectric layer Si_3N_4, obtained by plasma chemical deposition from the gas phase [1-4], was used. Using the experimental mode of formation allows you to achieve the growth rate of the dielectric layer V_G = 11.5 nm/min.

A structure for the growth of carbon nanostructures was formed on the experimental samples. By the method of magnetron sputtering a catalytic nickel layer was obtained. The thickness of the deposited nickel layer varied to about 5 μm. After that, using the method of plasma chemical vapor deposition, an additional layer of Si_3N_4 dielectric with a thickness of 10 μm was formed on the surface of the formed structure. By combining the methods of lithography and plasma chemical etching, a field emitter layout was formed, which provides voltage supply and the formation of the upper electrode, as well as the control electrode. The frame, namely the walls of the field emitter, made of a dielectric material, make it possible not only to protect the active emission region from mechanical impact from the outside, but also to prevent the formation of an electrostatic voltage that prevents the emission current from flowing. Additional modification of the nickel layer relief using plasma techniques allowed us to obtain a vertically oriented array of nickel whiskers, the working surface area of which was set by the etching time and the power of the plasma used. Carbon nanostructures were formed over the array by plasma chemical deposition from the gas phase. The parameters of the growth process were as follows: a temperature of 650 °C, a gas pressure of 100 mTorr and a working gas velocity of C_2H_2 – 30 cm^3/min and H_2 – 10 cm^3/min. After that, electrical contacts were formed over the sensitive layer, which were connected to a signal processing device. The formation time was 5 minutes. On top of the sensitive layer, electrical contacts were formed that connected to a signal processing device.

The experimental models obtained are distinguished by a high degree of adhesion, and the formed array of carbon nanostructures of the active emission region has a sufficient degree of perpendicularity to the substrate, which made it possible to obtain structures with a high aspect ratio. In addition, the data showed that the field emitter based on carbon nanostructures, formed using the above formation modes, is able to achieve the following parameters: the threshold field strength of the onset of emission is $E = 6.7\cdot10^8$ V/m, the electron work function ranges from 3.1 to 5.3 mA/cm^2, as well as the field gain coefficient $\beta = 7.9\cdot10^7$.

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